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RESEARCH MEMORANDUM

DYNAMIC CORROSION IN AN IRON - STAINLESS STEEL

TOROID BY SODIUM AT 900° F

By Robert A. Lad ✓

Lewis Flight Propulsion Laboratory
Cleveland, Ohio

FOR REFERENCE

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DYNAMIC CORROSION IN AN IRON - STAINLESS STEEL

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SUMMARY

A corrosion investigation was conducted with molten sodium flowing at a velocity of 25 feet per second in a toroid of AISI type 347 stainless steel with an insert consisting of seven Globeiron tubes in parallel at the hot zone. A 500-hour test was run at a nominal outer wall temperature of 900° F with a temperature difference between the hot and cold sections of 40° F. Chemical analysis of the toroid contents indicated attack of the stainless steel as well as the Globeiron. Metallographic examination of a section from the cold zone showed the presence of a porous mass-transfer deposit 0.001 inch thick.

INTRODUCTION

The suitability of a system incorporating both AISI type 347 stainless steel and Globeiron for containing molten sodium has been studied under conditions of interest to the power reactor studies conducted by the Detroit Edison Company for the AEC. The test was run in a toroid circulating apparatus (ref. 1) which permits independent control of fluid velocity and temperatures in a system containing no pump, valves, nor flowmeter.

The experiment was conducted in a modified toroid specimen having two straight sections. One of the straight sections contained seven Globeiron tubes in parallel. The remainder of the specimen was AISI type 347 stainless steel. The Globeiron section comprised the center of the hot zone, while the opposing stainless-steel straight section formed the cooled zone.

The experiment was conducted at 25 feet per second for a period of 500 hours at a nominal outer-wall temperature of 900° F and a temperature difference of 40° F between the hot and cold sections of the toroid. The tube contents were analyzed chemically and metallographic studies were made of both the Globeiron section and the cold zone.

PROCEDURE

The circulating apparatus, upon which the toroid specimen was mounted, is described in references 1 and 2.

Fabrication of specimen. - The specimen (fig. 1) was designed and fabricated by the Detroit Edison Company. Two semicircular sections of 6-inch mean radius and a straight section $5\frac{1}{2}$ inches long were fabricated from AISI type 347 stainless steel tubing of $\frac{5}{8}$ inch outside diameter and 0.065 inch wall. The Globeiron test section was composed of seven parallel tubes $1\frac{7}{8}$ inches long of 0.210-inch outside diameter and 0.010-inch wall. The Globeiron tubes were held in position by stainless-steel tube sheets which were welded to the surrounding jacket. Two $\frac{1}{16}$ -inch holes were provided in each tube sheet. These permitted the replacement by sodium of the air in the space between the tubes and the jacket. This essentially stagnant sodium increased the heat transfer to the Globeiron tubes. Appropriate reducing sections resulted in an assembly $5\frac{1}{2}$ inches long. Small-bore vent tubes were welded to the toroid at the midpoints of each of the semicircular sections. Heliarc welding was used in all instances.

Filling of specimen. - The specimen was filled with sodium by the Knolls Atomic Power Laboratory. The toroid was connected into a pumped sodium system and the whole assembly filled with sodium at 350° F under 500 microns absolute pressure. The toroid was then flushed with 420° to 540° F sodium at 0.2 gallon per minute for 4 hours. "Cold trapping" during the 4-hour period reduced the oxygen content to 0.002 ± 0.001 percent by weight.

The system was partially drained, the toroid being so positioned as to trap a sodium pocket equal to 40 percent of the toroid volume. Helium blanket gas pressure was adjusted to 2 pounds per square inch gage at room temperature, and the vent tubes were flattened, cut, and inert arc-welded. A sample of sodium was withdrawn from the loading system and analyzed (table I).

The toroid was then leak-tested by heating to 850° F and holding for $1\frac{1}{2}$ hour with the vent tube welds down so as to be covered with liquid sodium. All other welds had been leak-tested with the mass spectrometer.

Instrumentation. - A total of 18 chromel-alumel thermocouples were spot-welded to the outside wall of the toroid. The thermocouple junctions were covered with pieces of asbestos paper to shield them from the beaded Nichrome heaters which covered the specimen surface. Three layers of asbestos tape were used as outer insulation. One thermocouple located on the Globeiron test section was used for temperature control. The remaining thermocouples were connected to a multiple-point temperature recorder.

Test procedure. - The specimen was clamped to the table of the circulating apparatus. An annular cooler was provided for directing compressed air onto the cold section. The temperature of the toroid was raised to 300° F and circulation was begun and adjusted to 25 feet per second. The temperature was then raised to 900° F and the air flow adjusted to yield a temperature difference of 40° F between the hot and cold sections. The test was run at these conditions for 500 hours.

RESULTS

Chemical analysis. - At the conclusion of the test, the toroid was stripped of instrumentation and then opened. The contents were dissolved with an ethanol-water mixture and the alcohol was driven off by heating. The resulting aqueous solution was analyzed for sodium and other metal ions which might result from the corrosion of the toroid. In table I are presented nominal analyses for Globeiron and AISI type 347 stainless steel, while table II contains the analysis of the aqueous solution. The analytical results indicate that both components of the toroid suffered attack. This is of interest in the light of experiments (ref. 3) with toroids composed entirely of AISI type 347 stainless steel. These resulted in negligible attack at 1500° F after 100 hours with a 40° F temperature difference. The two components would be expected to have little effect on each other if the attack were simply due to solution in sodium. The decrease in corrosion resistance in the two-component system may be due to galvanic effects.

Metallographic examination. - Sections cut from the hot (Globeiron) zone showed no change on visual inspection. However, the cold (stainless steel) zone was found to contain a very thin deposit of metal crystals (fig. 2). Photomicrographs of metallographic sections from the two zones are shown in figures 3 and 4. The hot zone gives evidence of uniform attack with rounding of corners but no intergranular penetration. The deposit in the cold zone is typical of mass-transfer deposits; it appears to be composed of a porous mass of small crystals. The measured maximum depth of 0.001 inch cannot be taken as an accurate measure of deposition because experience has shown these deposits to vary considerably in apparent density.

SUMMARY OF RESULTS

A corrosion investigation was conducted with molten sodium flowing at a velocity of 25 feet per second in a toroid made of AISI type 347 stainless steel with an insert consisting of seven parallel Globeiron tubes. A 500-hour test was run at a nominal outer wall temperature of 900° F with a temperature difference of 40° F. The results can be summarized as follows:

1. Metal was removed from the Globeiron surface in the hot zone uniformly and without intergranular attack.
2. Mass transfer to the cold zone was greater than found previously for a system composed entirely of AISI type 347 stainless steel. The maximum thickness of the porous deposit (of unknown density) was 0.001 inch.
3. Analysis of the toroid contents indicated that the sodium attacked both the iron and the stainless steel.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, February 2, 1954

REFERENCES

1. Desmon, Leland G., and Mosher, Don R.: Preliminary Study of Circulation in an Apparatus Suitable for Determining Corrosive Effects of Hot Flowing Liquids. NACA RM E51J12, 1951.
2. Mosher, Don R., and Desmon, Leland G.: Preliminary Investigation of Corrosion by Molten Sodium Hydroxide Flowing in Tubes of AISI 347 Stainless Steel, Inconel, and Nickel having Average Outer-Wall Temperatures of 1500° F and a Circumferential Temperature Gradient of 20° F. NACA RM E51J16, 1951.
3. Mosher, Don R., and Desmon, Leland G.: Dynamic Corrosion of AISI 347 Stainless Steel by Sodium at 1500° F. NACA RM E52G10, 1952.

TABLE I. - ANALYSIS OF STARTING MATERIALS

Sodium ^a		Globeiron, ^b percent		AISI type 347 stainless steel, ^b percent	
K	350 ppm	C	0.04	Ni	11
Li	10	Mn	.24	Cr	18
P	7	P	.015	Cb	.7
S	20	S	.025	Fe	bal.
Ca	35	Si	.01		
		Fe	bal.		

^aAnalyzed by Knolls Atomic Power Laboratory.^bNominal analysis.

TABLE II. - ANALYSIS OF TOROID CONTENTS

AFTER EXPERIMENT

Metal	Amount, g
Na	65.8
Fe	.021
Mn	.0017
Cr	.0088
Ni	.0011
Cu	.0003
Total metal pickup	.0329 (500 ppm)

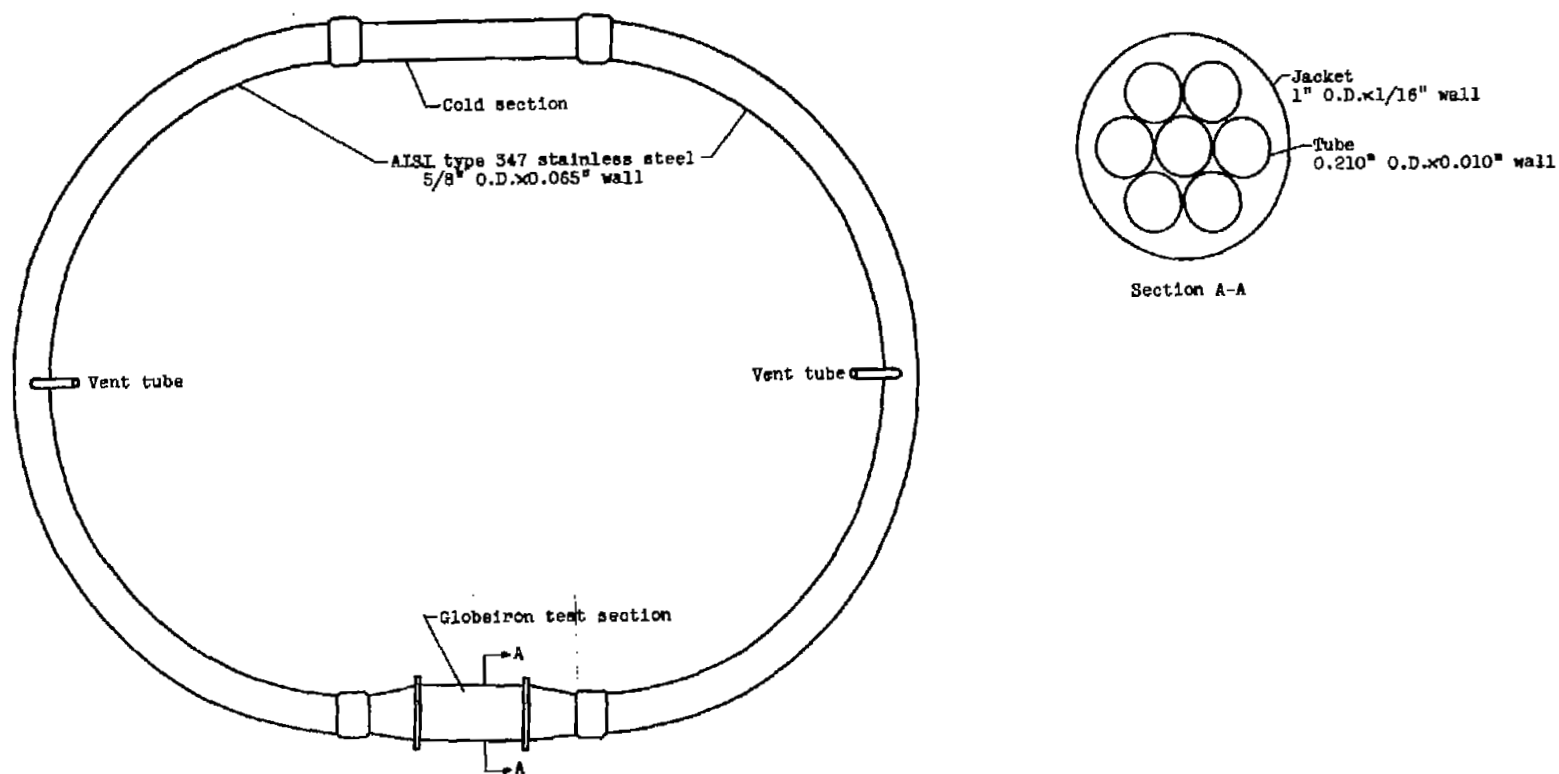


Figure 1. - Toroid test specimen.

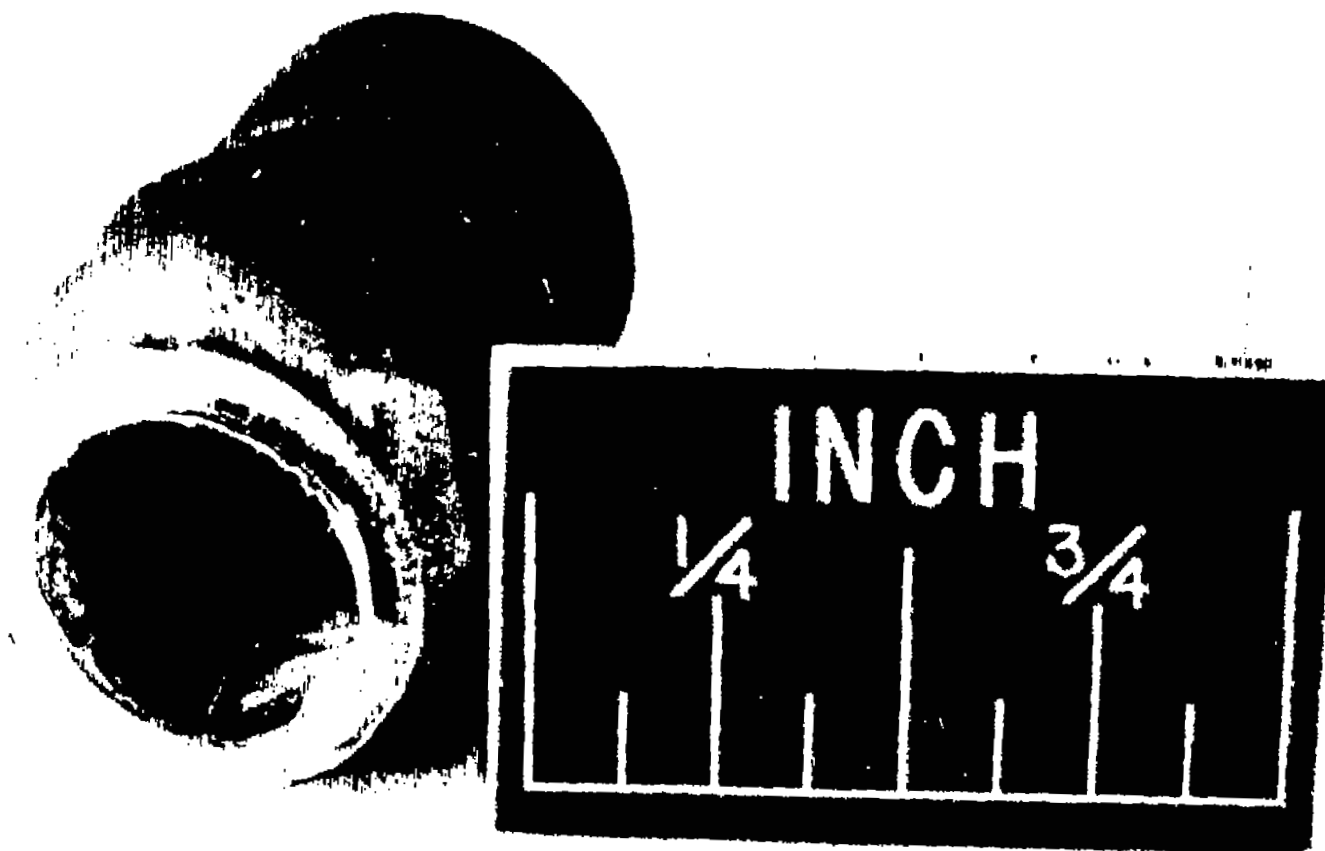
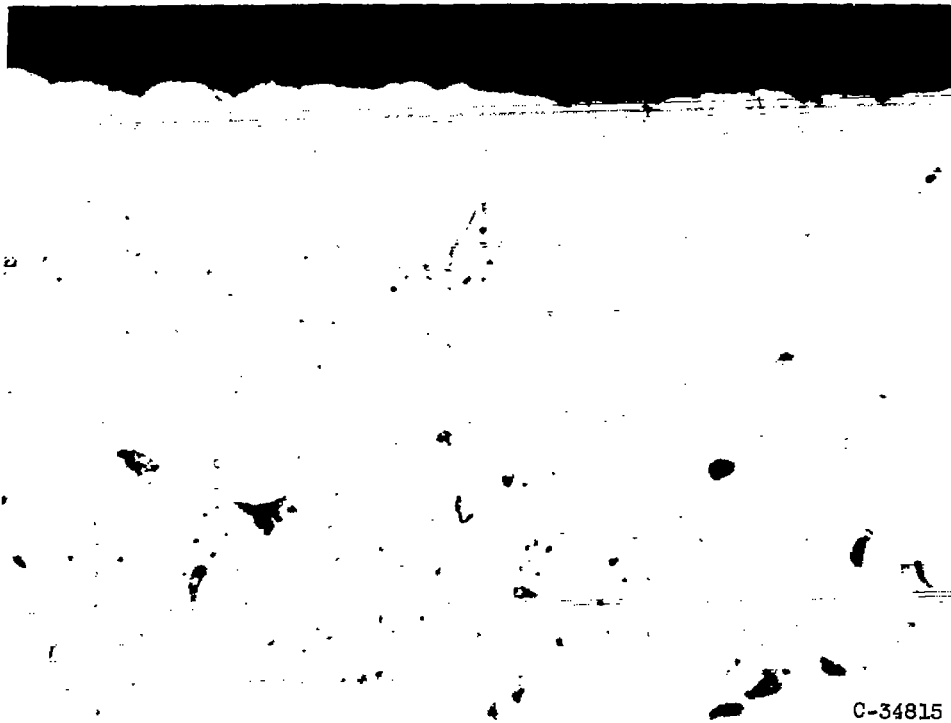


Figure 2. - Section from cold zone showing thin deposit of metal crystals.

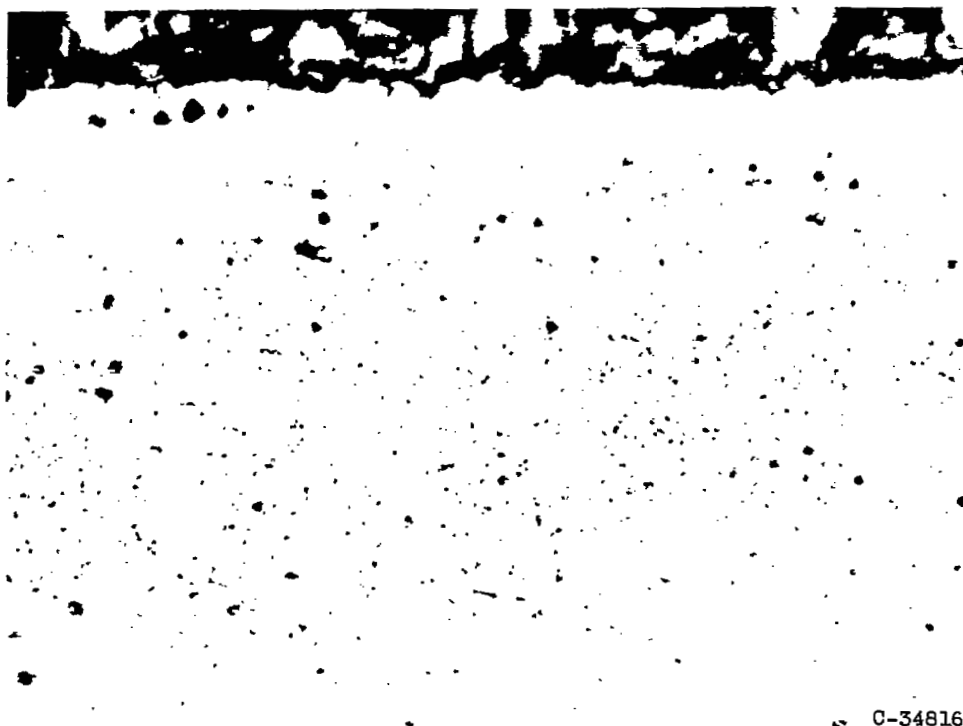
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Figure 3. - Attack in hot zone showing rounding of corners with no intergranular penetration.

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Figure 4. - Cold zone showing porous deposit of metal crystals.

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